Advanced Management and Protection of Energy storage Devices (AMPED)

2nd Annual Program Meeting

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Program Director, ARPA-E

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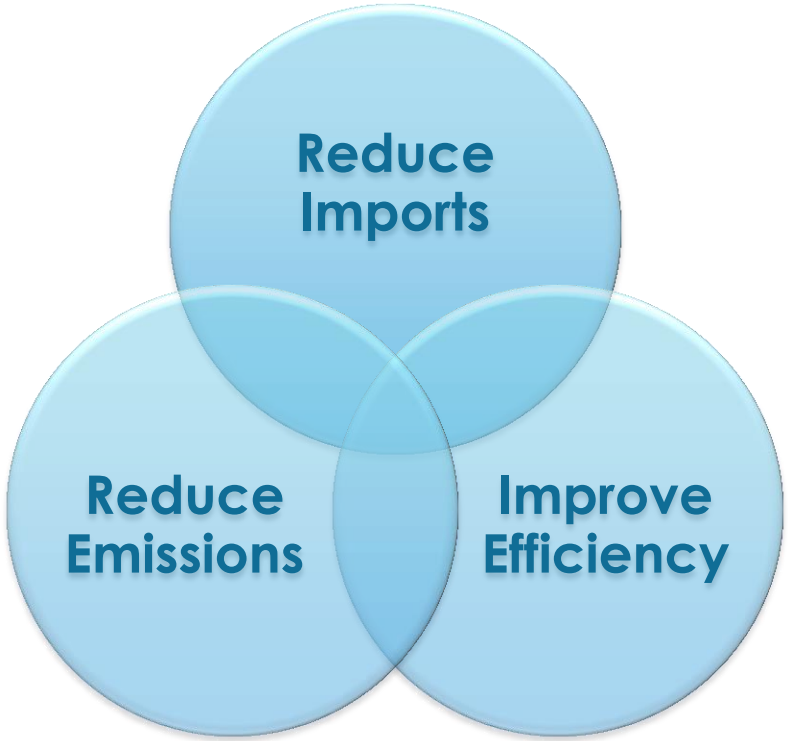
Our Mission

Catalyze and support
transformational, high impact energy technologies

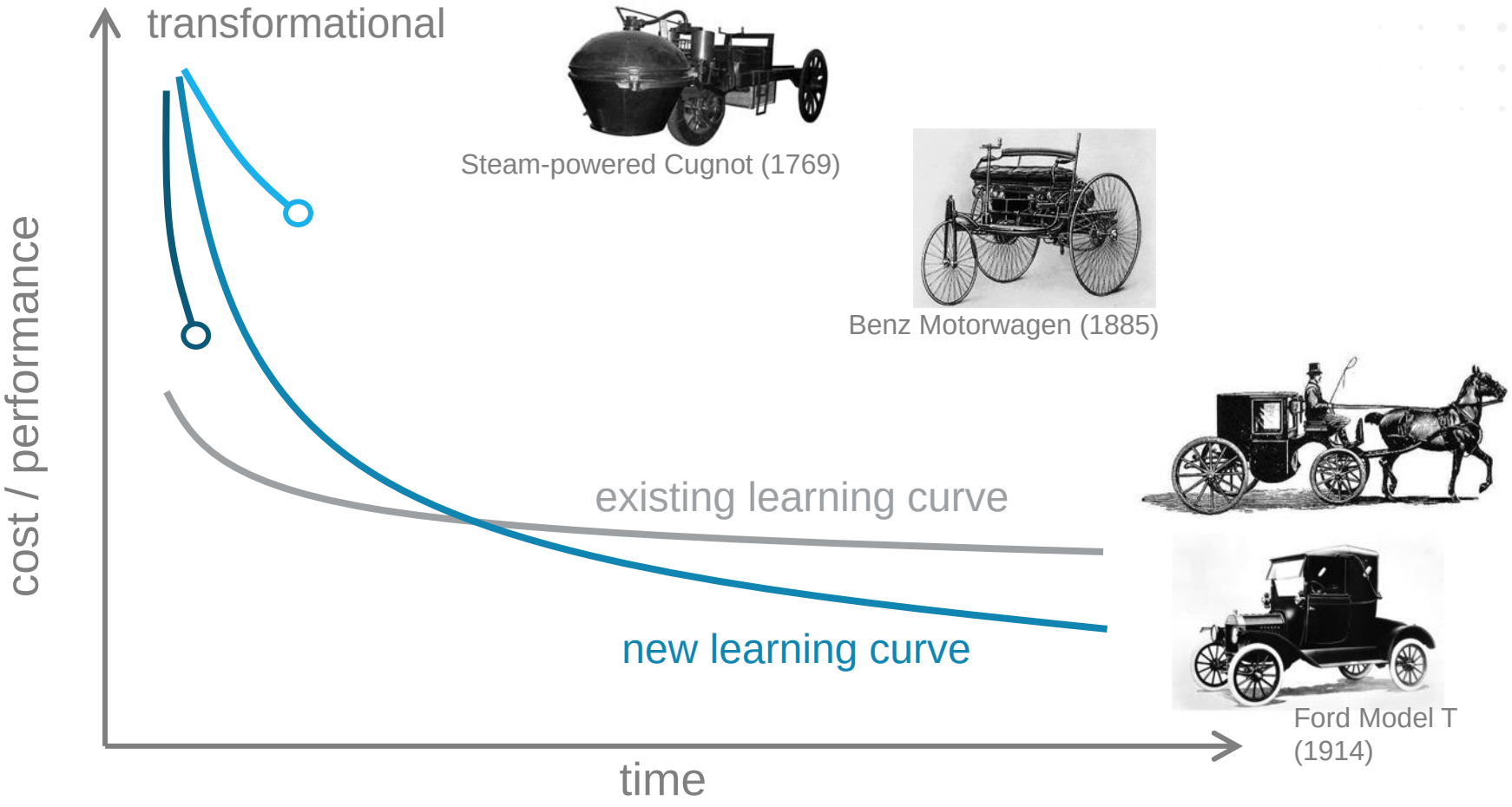
Ensure America's

- Technological lead
- National security
- Economic security
- Environmental security



Our Approach

Transformational technologies that lead to new learning curves



Steam-powered Cugnot (1769)

Benz Motorwagen (1885)

Ford Model T (1914)

ARPA-E: 14 Focused Programs to Date (01/2013)

Transportation

Electrofuels

BEEST

PETRO

MOVE

Transportation and Stationary Power / Use

HEATS

REACT

AMPED

SBIR/STTR

Stationary Power / Use

BEETIT

IMPACCT

GRIDS

ADEPT

GENI

Solar ADEPT

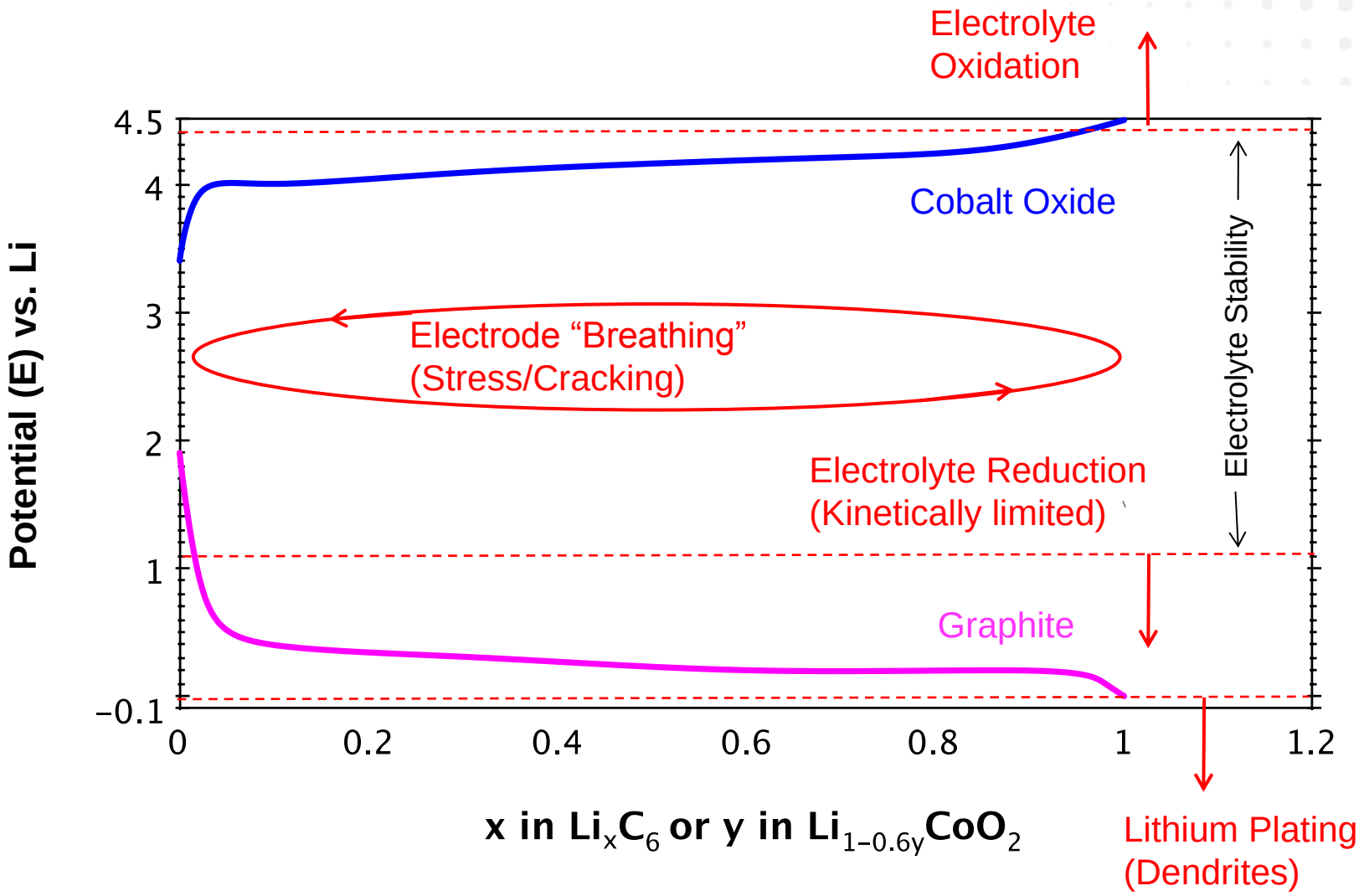
Can’t we do better with today’s chemistries?

Balance of System	Physical protection Thermal management Charge balancing State monitoring Etc.
Overhead Capacity	Additional capacity buffer: safety/lifetime assurance
Base Capacity	Capacity needed to meet load requirement

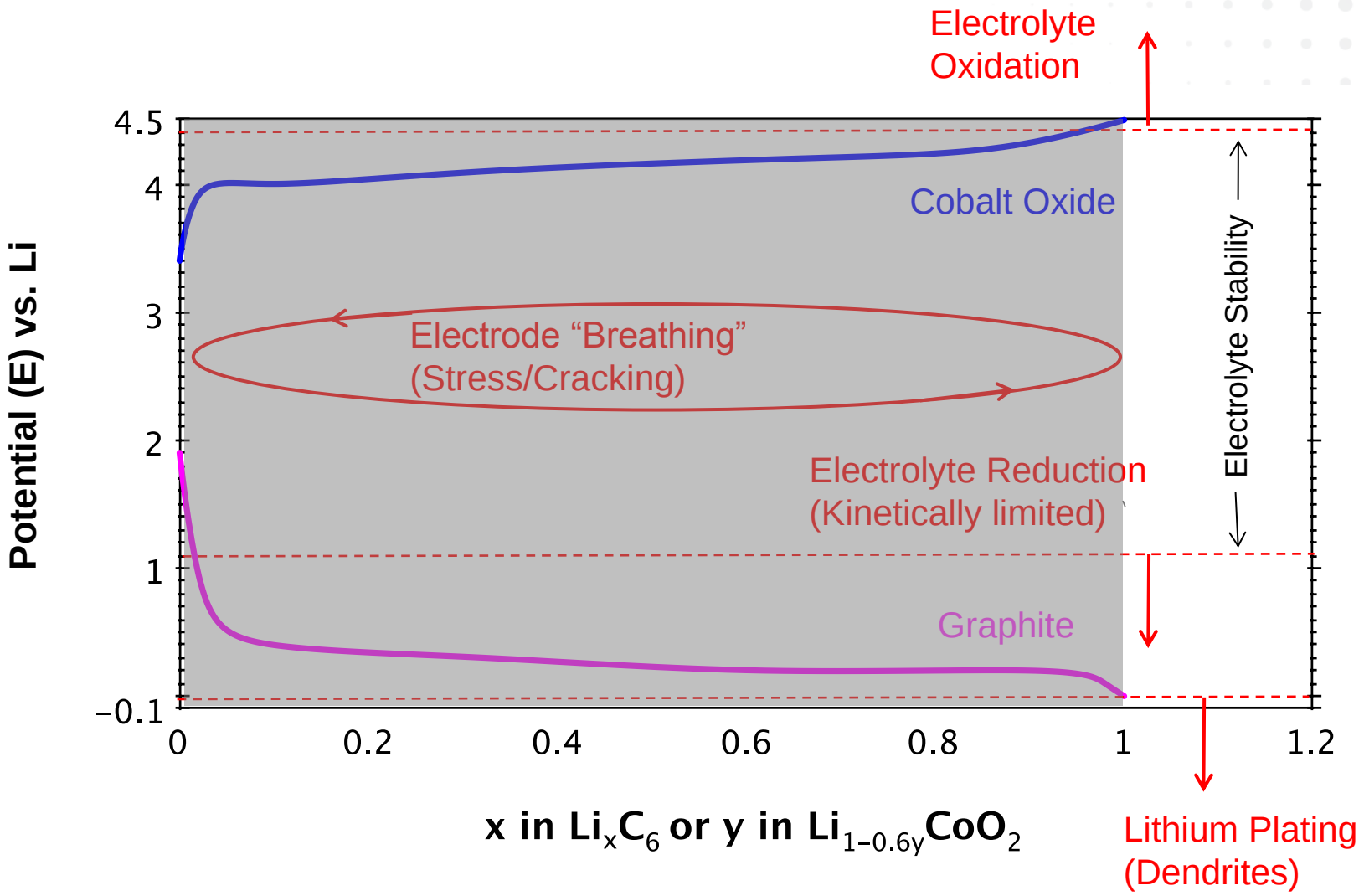
State-of-the-Art Storage System

Image Source: http://http://jcwinnie.biz/wordpress/

What are we protecting against?



Utilization Constraints



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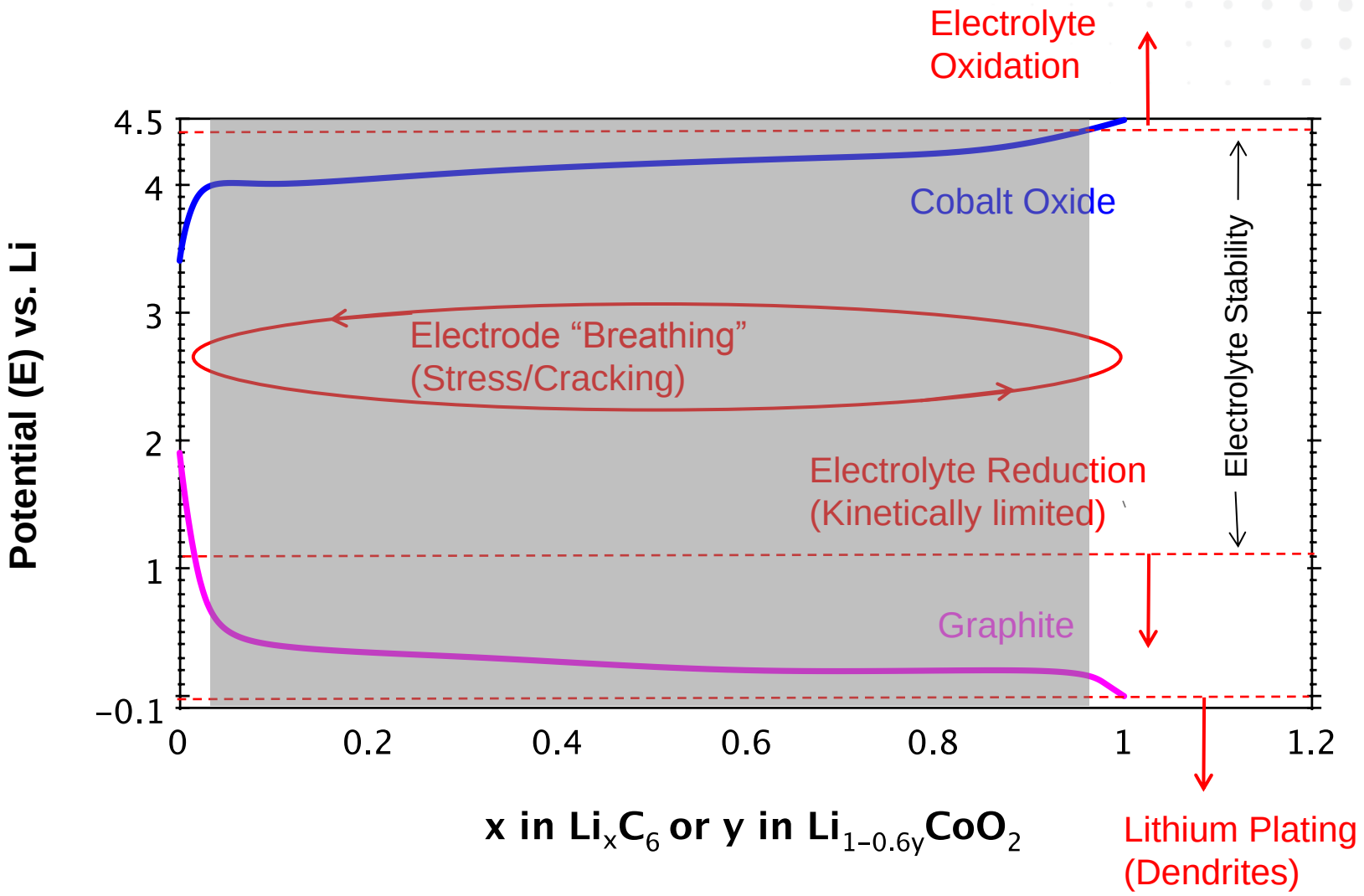

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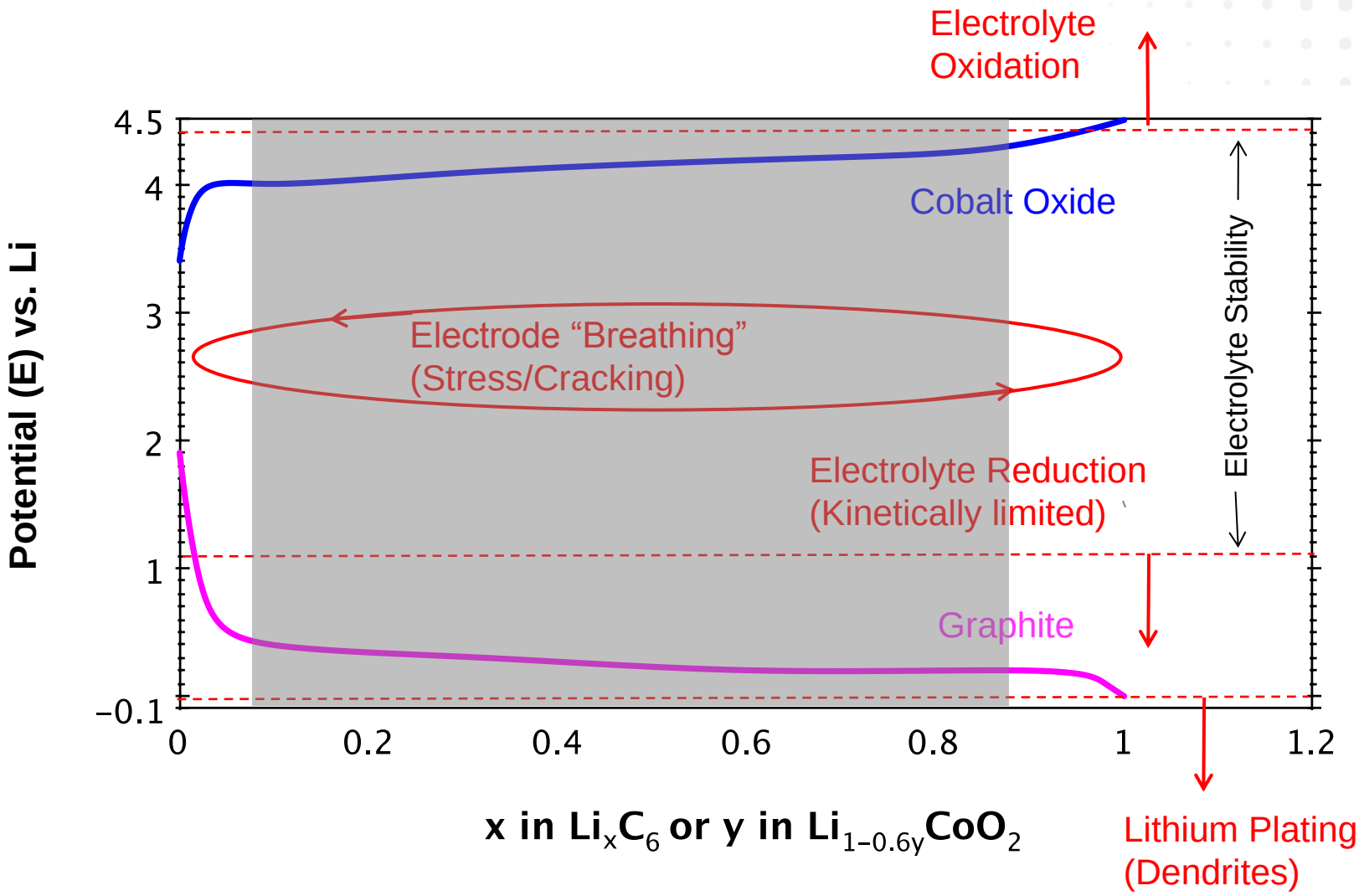

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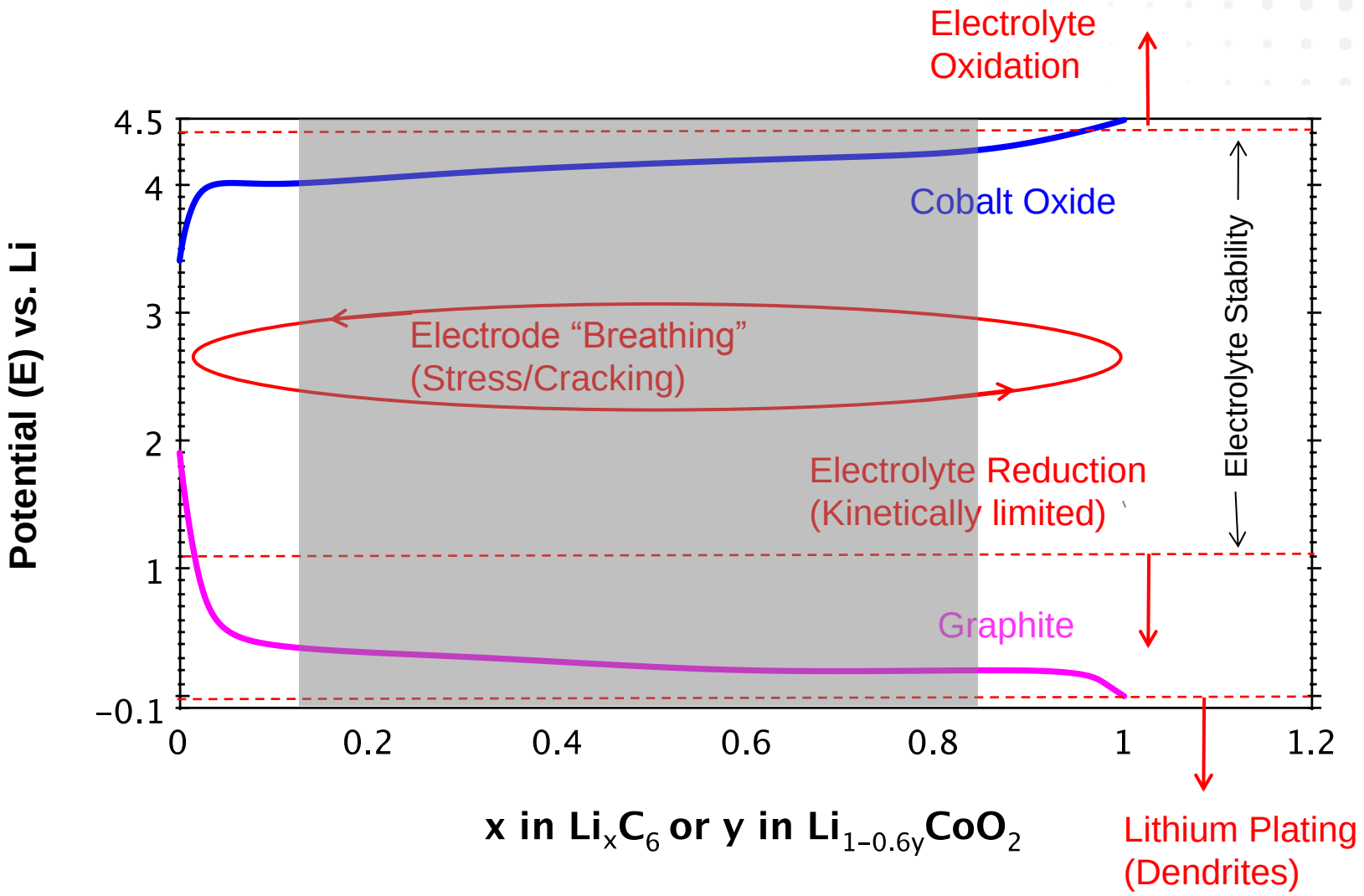

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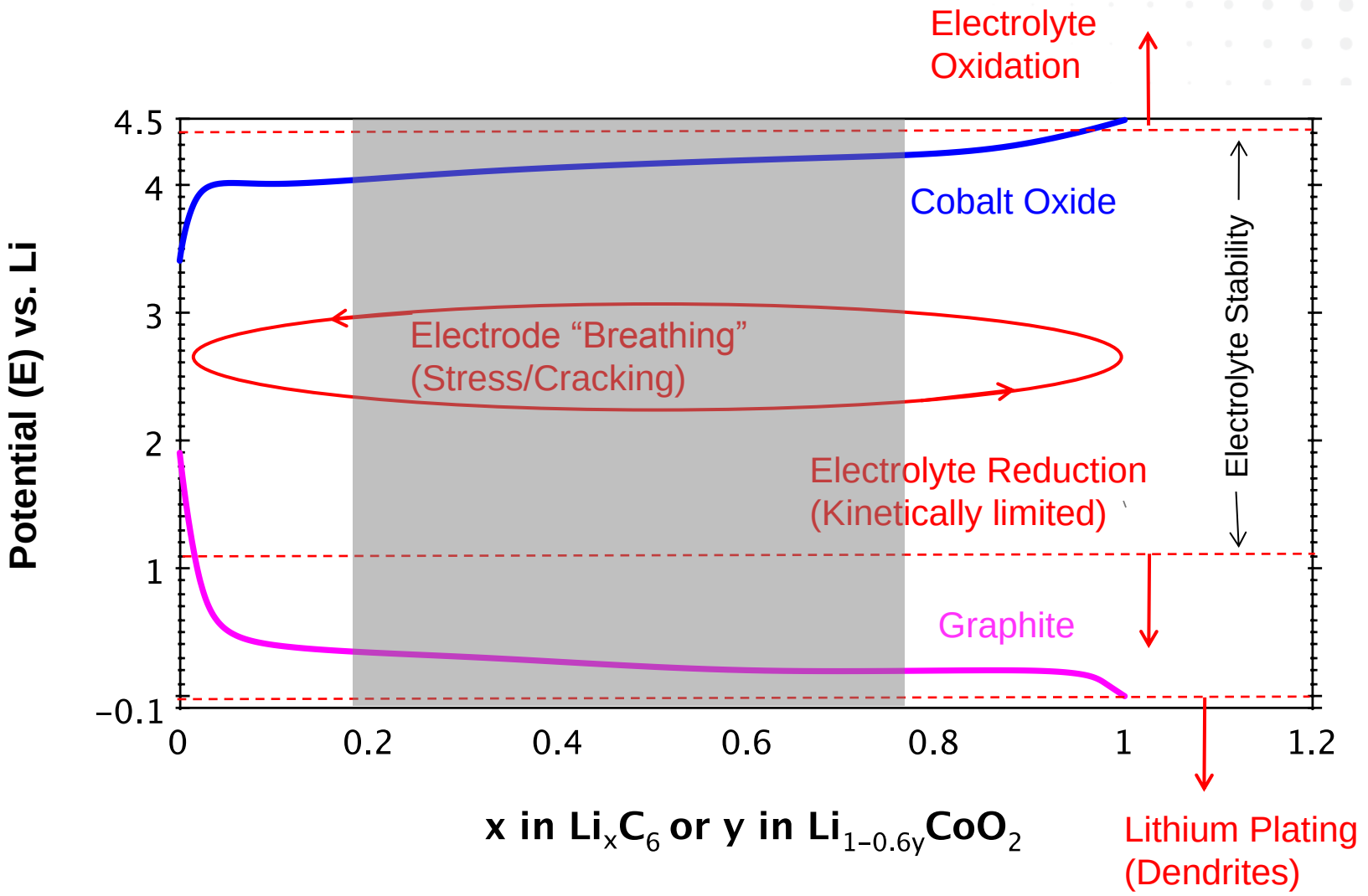


Removing the Blinders

Inside every cell

Groups of cells

What we are protecting against

Electrolyte oxidation / reduction

Lithium Plating (Dendrites)

Electrode stress/cracking

Internal cell defects

Thermal runaway

What we currently monitor

Temperature

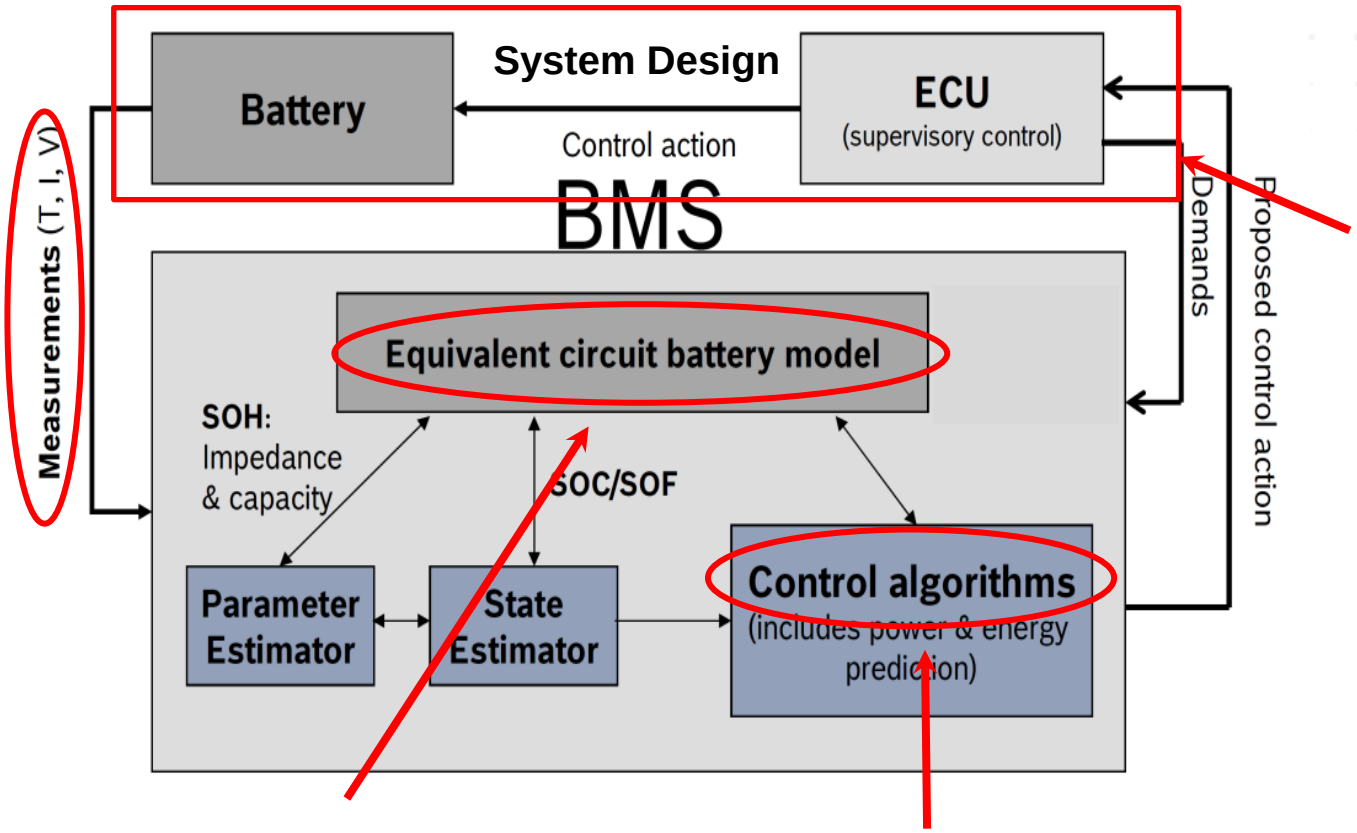
Voltage

Current

Image Source: http://www.web-site-building-tips.com/what-is-business-research.html

Many opportunities for disruptive BMS innovation

1. Sensing provides only indirect state information with low spatial resolution

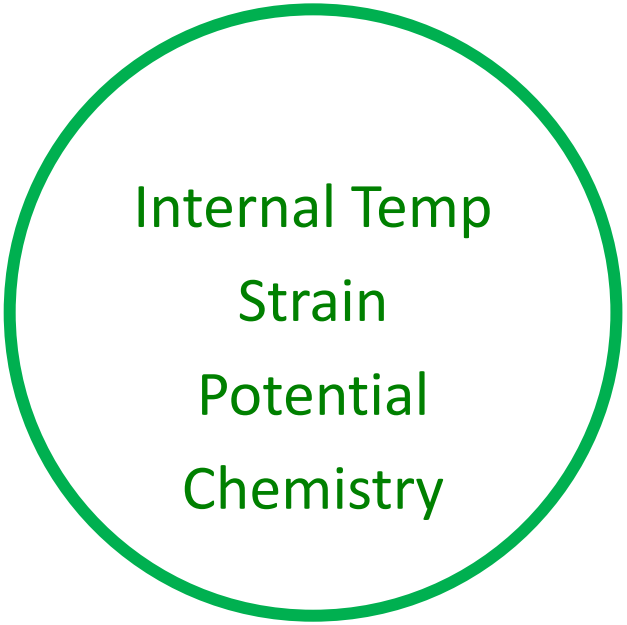


4. Little system flexibility : direct wiring, passive balancing, modular monitoring and control

2. Simple equiv. circuit models, heuristically validated, limited accuracy

3. Simple rule-based control imposes “static” and conservative constraints

The AMPED Portfolio

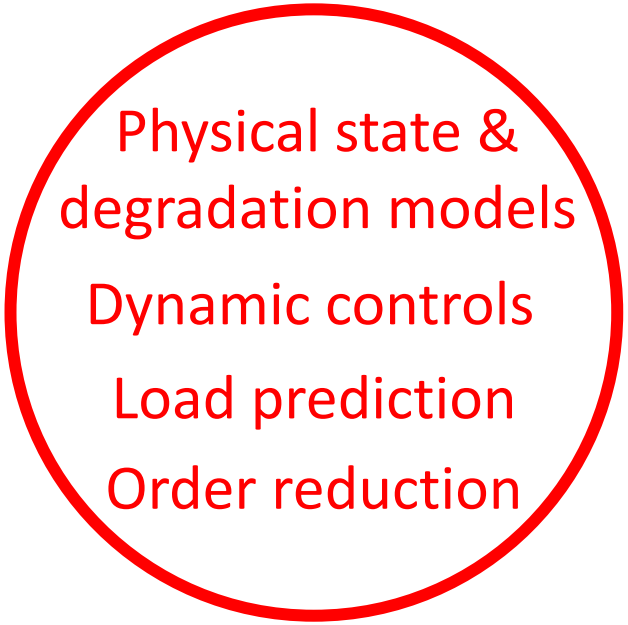


Awareness
(Informational)

Understanding
(Analytical)

Flexibility
(Physical)

The AMPED Portfolio



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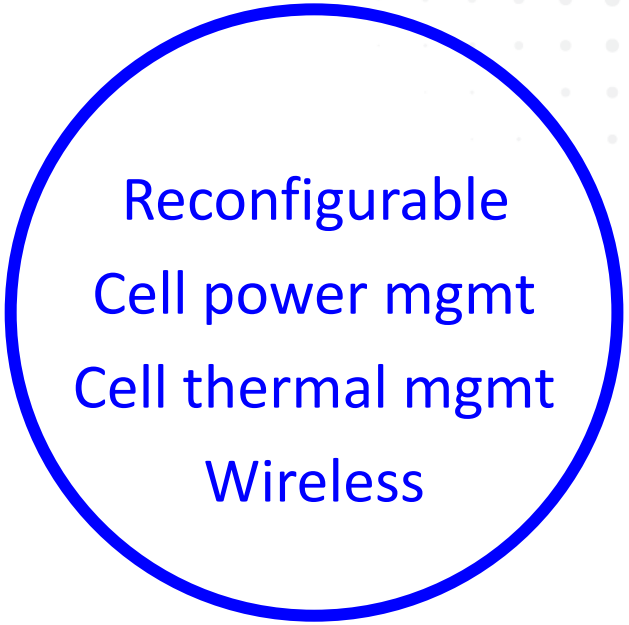

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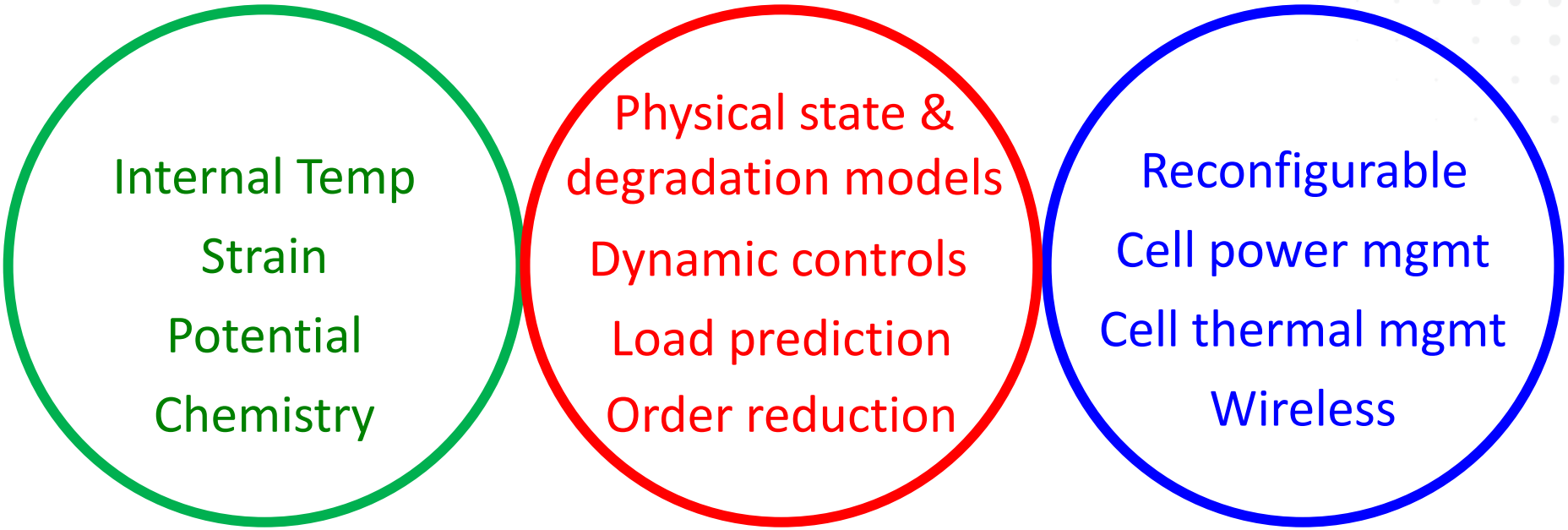

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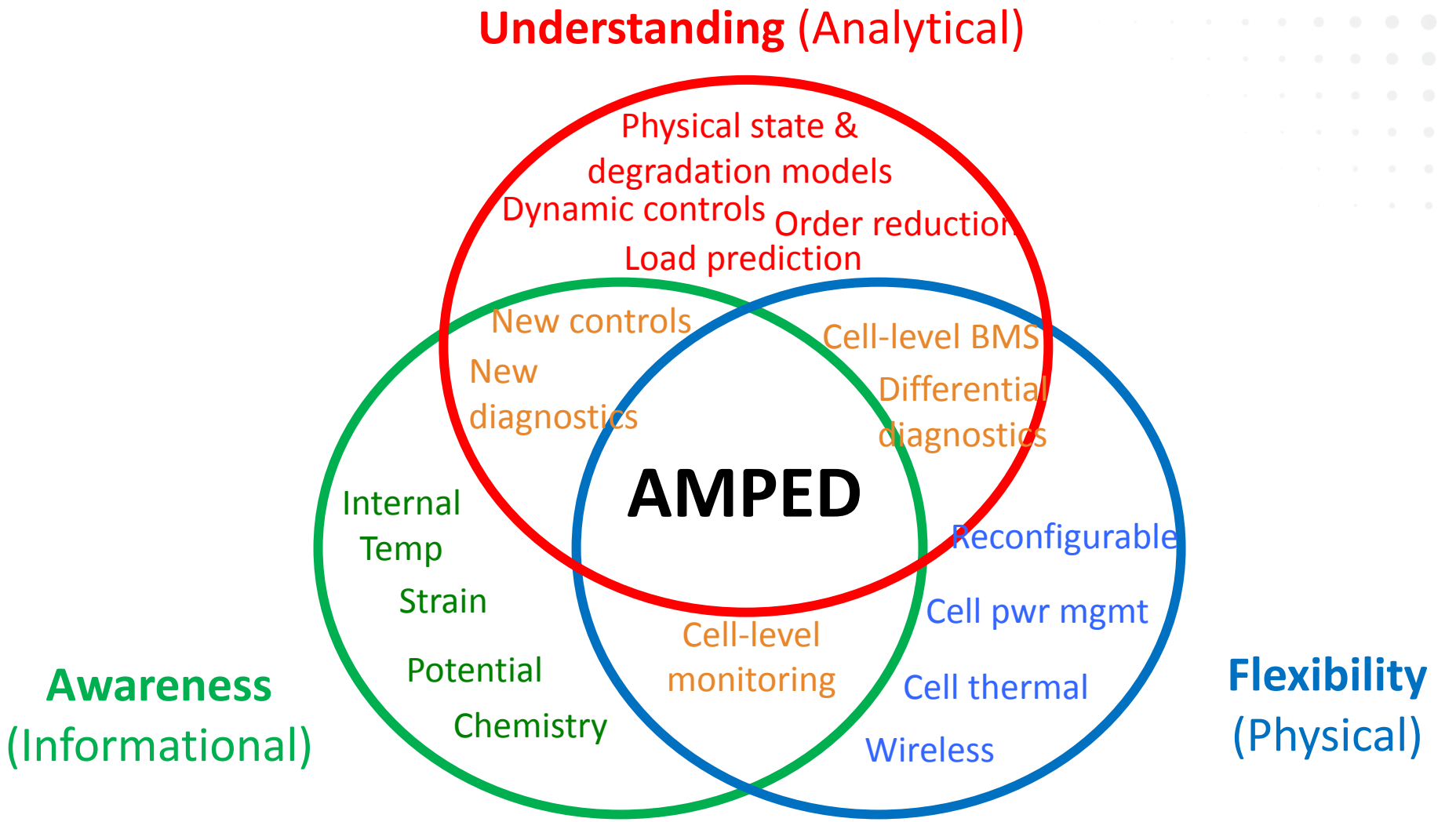
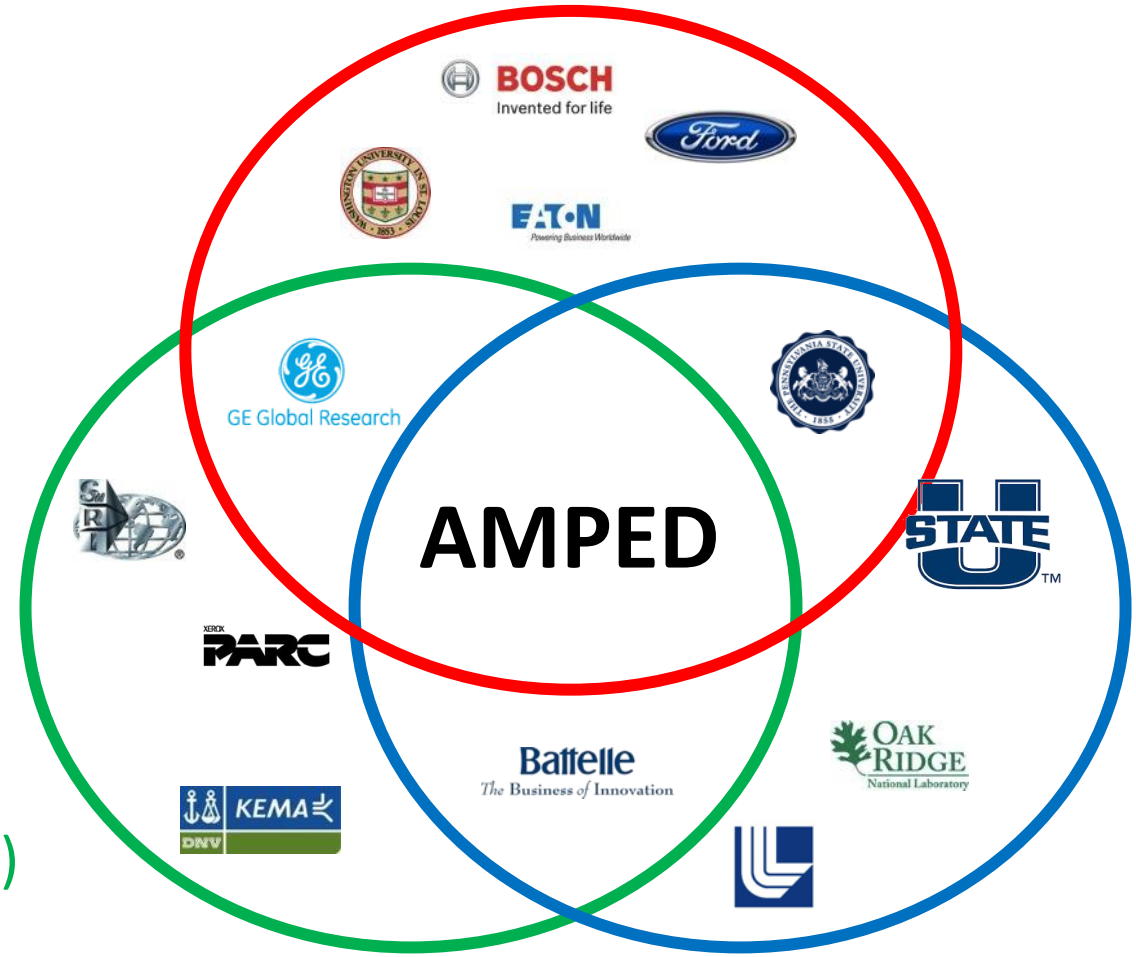


The AMPED Portfolio

Understanding (Analytical)

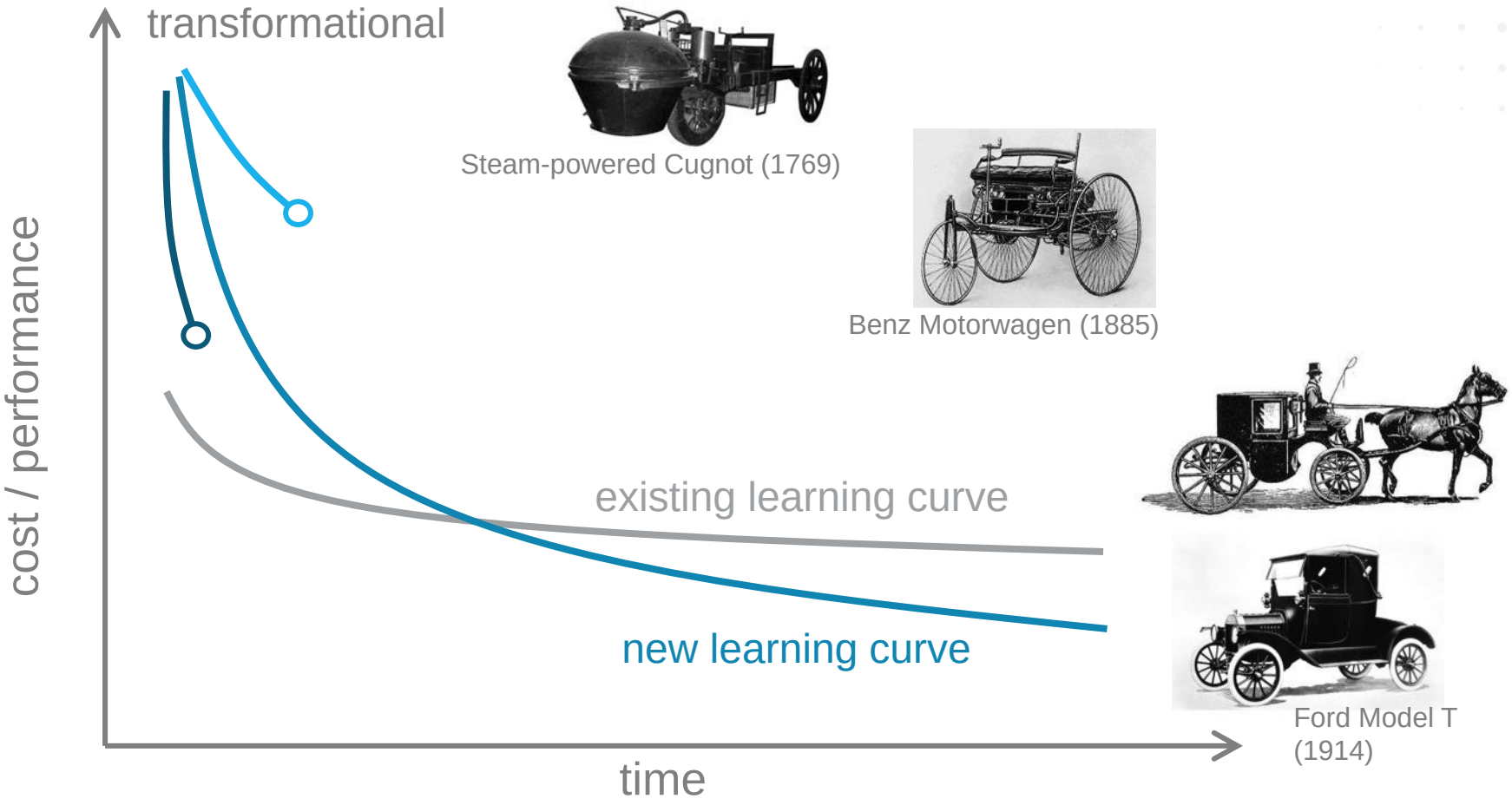


Awareness (Informational)

Flexibility (Physical)

Our Approach

Transformational technologies that lead to new learning curves



Steam-powered Cugnot (1769)

Benz Motorwagen (1885)

Ford Model T (1914)

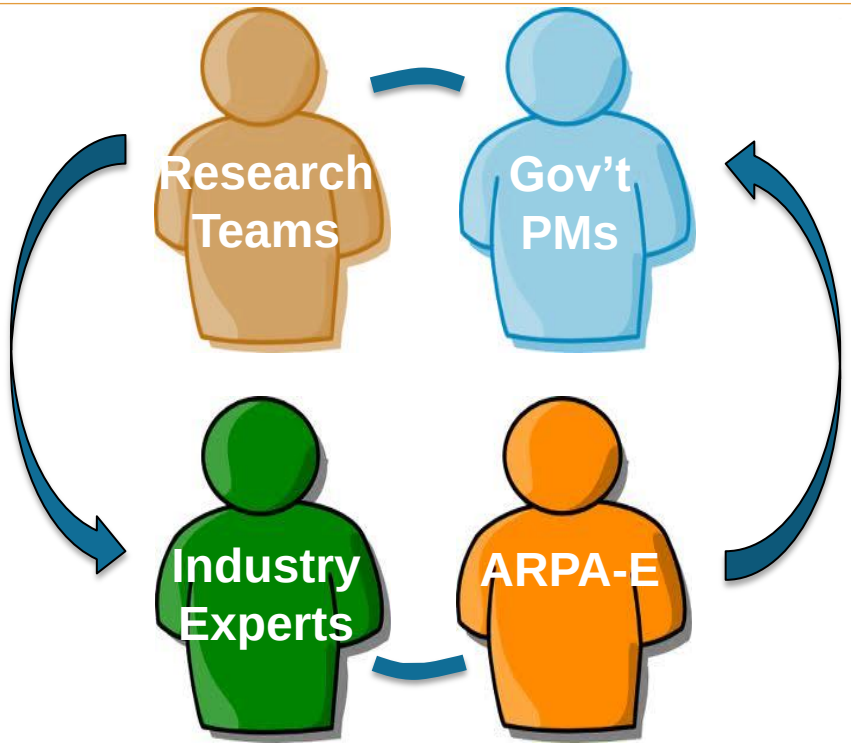
Annual Meeting Objectives

Knowledge

Cross-disciplinary learning about issues and opportunities

Learning and industry insights for researchers & gov't

Updates on AMPED R&D for industry and gov't



Community

Relationships

Potential collaborations between research teams

Industry engagement to improve and gain access to research

Future development opportunities within industry and gov't

Meet the ARPA-E Folks

Cheryl Martin

Eric Rohlfing

Ping Liu

Tim Heidel

Pat McGrath

Sue Babinec

Russell Ross

Kevin Thompson

Agenda - Feedback from Last Year

- **Top 5 things that worked well**
  1. Project pitches
  2. Tutorials
  3. Interaction/networking
  4. Industry and guest speakers
  5. Facebook

- **Top 5 recommendations for improvement**
  1. More time/depth on projects
  2. More panels and interactive sessions
  3. Wish I could have attended more than one tutorial
  4. Expand dialogue beyond EV
  5. Cheaper reception

Agenda

Wednesday

Cross discipline tutorials

Project updates: (1) Novel sensing

(2) Modeling, controls, diagnostics

(3) Dynamic systems

Poster and networking session

Thursday

Automotive industry panel

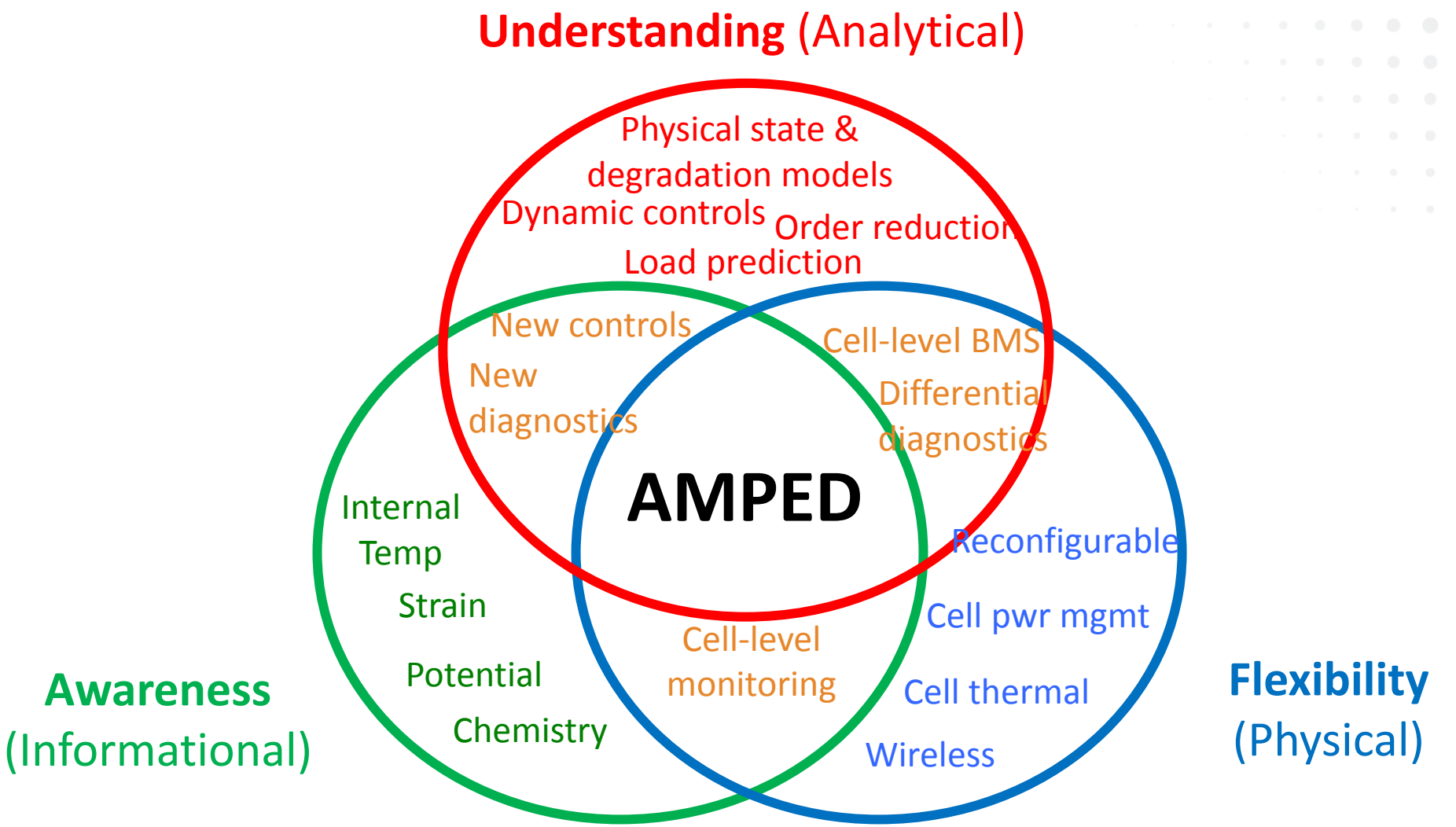
Stationary industry panel

Defense overview and panel

Supplier perspective panel

AMPED Next Steps

The AMPED Portfolio



Imagine a world…

Imagine a world…

- Integrated sensors
- Power conversion
- Control and diagnostics
- Wireless readout

The life of a cell

Cell birth

The life of a cell

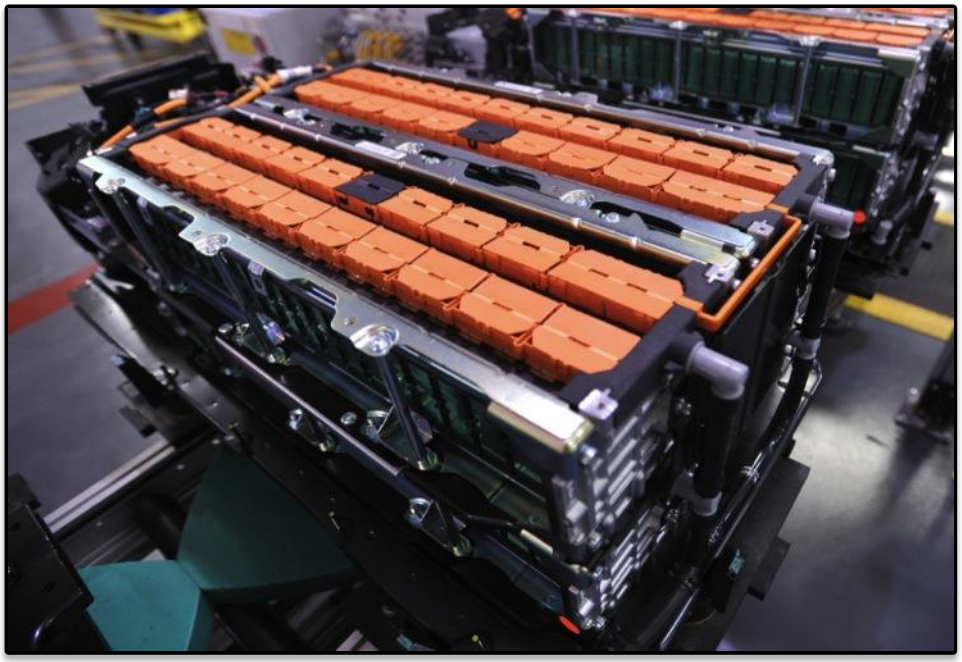
Qualification and binning

The life of a cell

Storage and shipping

The life of a cell

A pack is born



The life of a cell

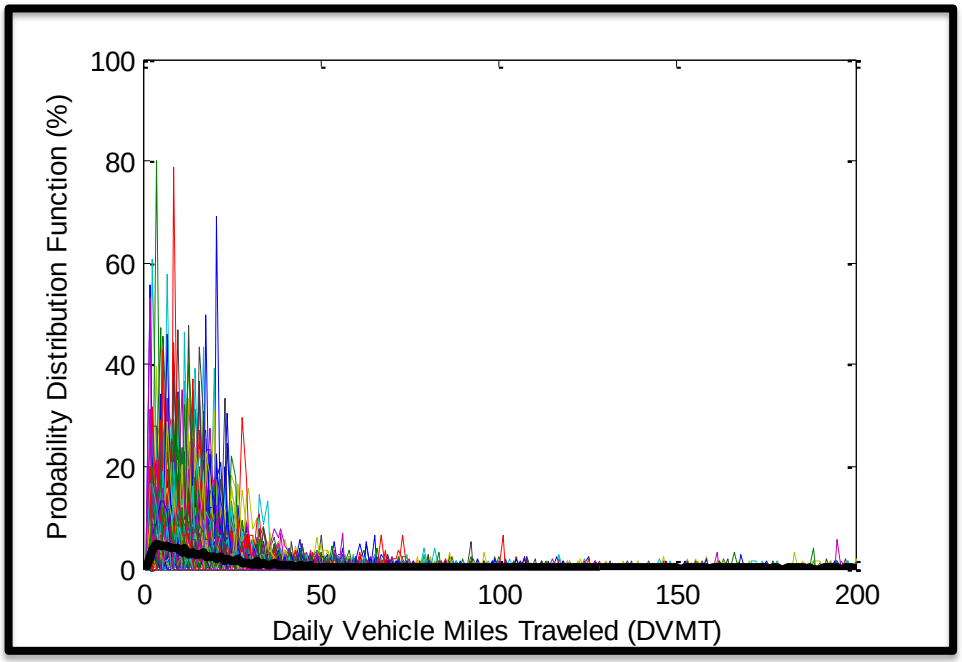
More testing

The life of a cell

Life on the open road

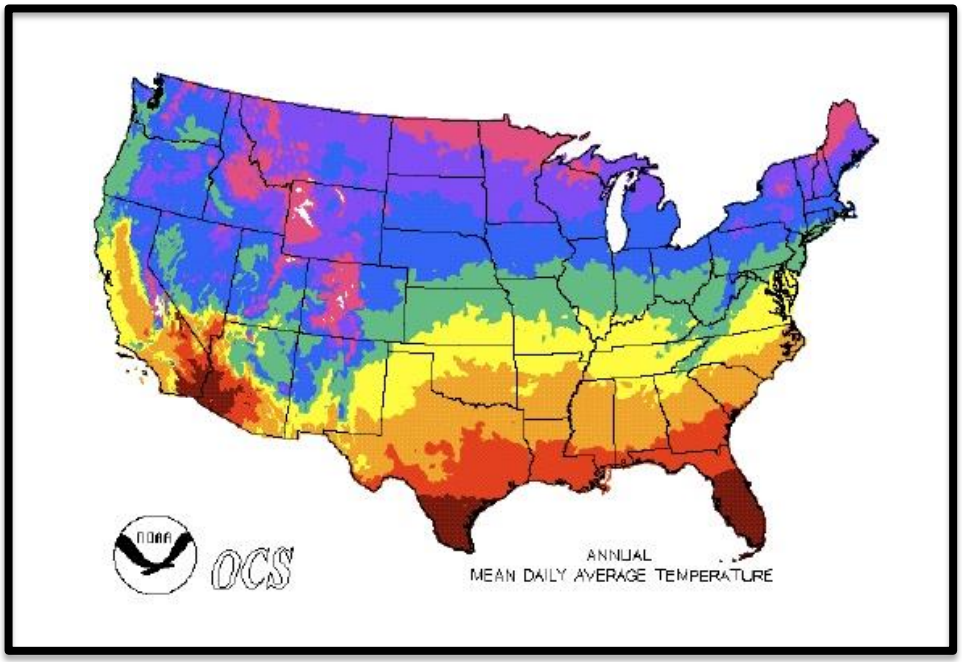
The life of a cell

Life on the open road



The life of a cell

Life on the open road



The life of a cell

Life on the open road

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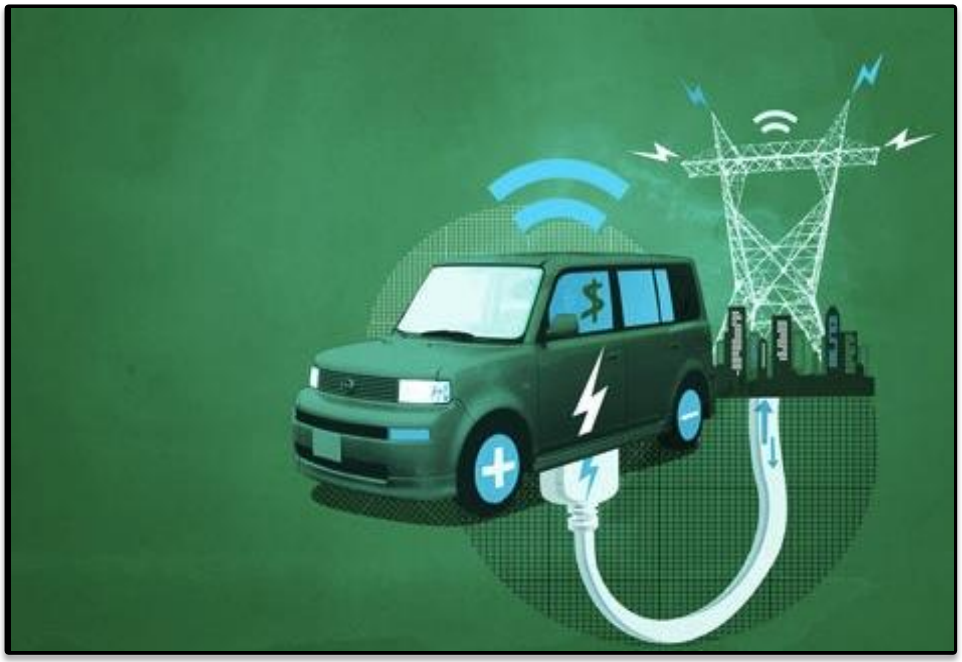


The life of a cell

Life on the open road

The life of a cell

A pack in unborn

The life of a cell

Born again

The life of a cell

RIP

Back to reality

Back to reality

1. The technologies you described don't exist
2. Even if they did exist, they won't give us that much benefit
3. And they won't be affordable enough

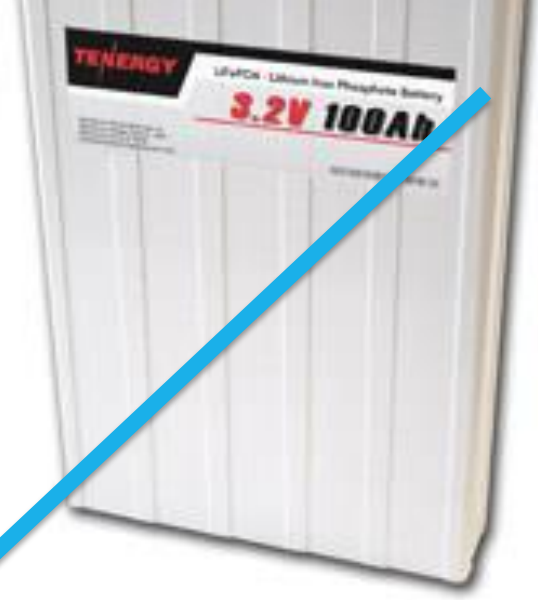
Times they are a changin’

$2/cell

200% cost for 3 years protection and optimization

$20/cell

20% cost for 10 years protection and optimization



$100/cell

4% cost for 30 years protection and optimization

Combine techs for cost leverage

- Integrated sensors
- Power conversion
- Control and diagnostics
- Wireless readout

Back to reality

DAY 1

1. The technologies you described don't exist
2. Even if they did exist, they won't give us enough benefit
3. And they won't be affordable enough

DAY 2

4. Yes, but the benefit is split up across too many players
5. Can you even do this w/o the cell manufacturers involved?
6. How would you validate what the optimal combination is?

Sometimes imagination prevails

Sometimes imagination prevails

Sometimes imagination prevails

Advanced Systems Engineering and Intelligent Balance-of-System Can Help Meet the SAI Levelized Energy Cost Goals

- **Improved and Optimized Total PV System** *Performance*
- **Higher System** *Reliability* **and System Lifetimes**
- **Lower Initial Installation** *Costs* **and More Standardized Designs**
- *Value Added:*
  - ***Through Intelligent Controls and Energy Management***

Sometimes imagination prevails

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1 Enphase Microinverter

Benefits

- Maximum energy production
- No single point of system failure
- Quick and simple design and installation
- Innovative cabling for fast and flexible installation
- Only low-voltage DC, standard AC

2 Envoy Communications Gateway

Benefits

- Plug and play setup
- 24/7 monitoring and analysis
- Advanced data management and storage

3 Enlighten

Benefits

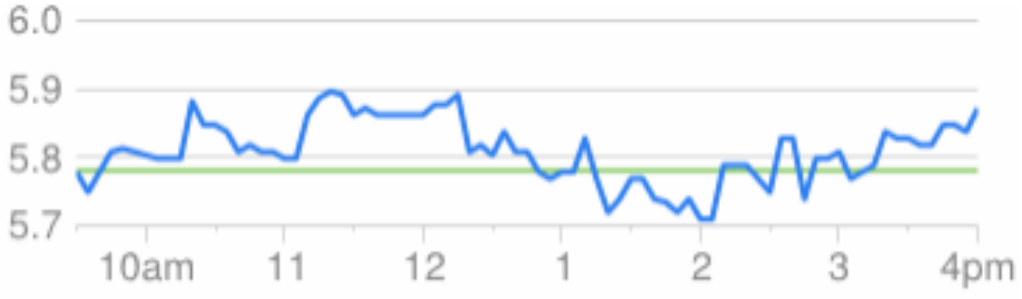
- Included at no additional cost
- Unprecedented insight and analysis
- Remote diagnostics and maintenance

Sometimes imagination prevails

Enphase Energy Inc

NASDAQ: ENPH - Dec 27 4:00 PM ET

5.87 +0.09 (1.56%)



1d | 5d | 1m | 6m | 1y | 5y | max

Open	5.78
High	5.90
Low	5.70
Volume	265,169
Avg Vol	397,000
Mkt Cap	246.78M

Google Finance - Yahoo Finance - MSN Money

Disclaimer

Sometimes imagination prevails

Enphase

SMA (Sunny Boy)

Power One

Enecsys

Solarbridge

Solar Edge

Agenda

Wednesday

Cross discipline tutorials

Project updates: (1) Novel sensing

(2) Modeling, controls, diagnostics

(3) Dynamic systems

Poster and networking session

- Must attend session with least expertise
- THANK YOU to our instructors